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EFFECT OF IRRADIATION DOSE, TEMPERATURE AND FAT LEVEL ON THE COLOR INTENSITY AND TEXTURAL CHARACTERISTICS OF BEEF ROLLS

by
Vera C. Mason
Gary W. Shults
Joseph S. Cohen
and
Vicki Loveridge

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U.S. Army Soldier and Biological Chemical Command
Soldier Systems Center
Natick, Massachusetts 01760-5018

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This report describes work performed on irradiated beef slices prepared from beef rolls that contained different fat levels (5, 20 and 35%), given different irradiation doses (37 and 74 kGy) and irradiated at temperatures ranging from +5 to -80 degrees centigrade. They were evaluated for color, texture and preference by sensory panels. The color and texture were also measured instrumentally. The beef slices were evaluated with no storage and after one year of storage at room temperature. The irradiation had no effect.

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PREFACE

This report describes research conducted by members of the Irradiated Food Products Group, Radiation Preservation of Food Division, Food Engineering Laboratory, US Army Natick Research and Development Command in 1970.

It is being published now as the Army has expressed a need for irradiation sterilized meat products. The data is relevant.

Beef rolls of varying fat levels were prepared and irradiation sterilized. The beef contained 0.75% NaCl and 0.38% NaTPP. The doses given were 37 and 74 kGy. The temperature of irradiation ranged from +5 to -80 ^{o}C. They were evaluated for color, texture and preference by sensory panels. The textural changes were measured with a Shear Press. The color changes were measured with a reflectance tristimulous colorimeter. The samples were evaluated with no storage and after one year of storage at room temperature.

High dose rates had a degrading effect on the color and texture. The irradiation temperature had no effect.

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EFFECT OF IRRADIATION DOSE, TEMPERATURE AND FAT LEVEL ON THE COLOR INTENSITY AND TEXTURAL CHARACTERISTICS OF BEEF ROLLS

Introduction

The objective of high dose irradiation is to create shelf-stable commercially sterile foods by the elimination of spoilage and/or disease causing bacteria with a cold, rather than a high-heat, process such as retorting (commercial canning). The "cold" irradiation process produces highly acceptable products, ones that are familiar in appearance, yet completely stable when stored at room temperature. Despite the advantages, high-dose ionizing radiation has not been commercially accepted in this country due to the lack of regulatory approval by the Food and Drug Administration (FDA).

Irradiation is considered to be a cold process since there is only a slight rise in temperature during processing. The general appearance, taste, texture, color and odor characteristics are only slightly affected. These foods are highly acceptable to the consumer. (NRDC, 1975).

The effect of irradiation processing on the nutritive value of foods are not different in degree from other methods of food preservation. There is less destruction of nutrients when the food is held at low temperatures during irradiation (Thomas and Josephson, 1970) and by reducing free oxygen from the radiation environment (Southern and Rhodes, 1967 and Raica et al. 1972). The irradiated foods are as nutritious as thermally processed foods.

Purpose

This study was conducted to determine the effect of irradiation processing on the color and textural characteristics of beef rolls with three fat levels. It was expected to demonstrate the degrading effects on the color and texture with increasing radiation dose. Additionally, the protective effect of cryogenic irradiation should be shown. The results were determined subjectively by technological panels and objectively with physical testing apparatus. The data were analyzed by analysis of variance techniques.

Color

Irradiation processing causes pronounced color changes in beef, pork, chicken and lamb that have been pre-heat treated for enzyme inactivation. It appears that food derived from these more domesticated animals are more sensitive to irradiation (Sudarmadji and Urbain, 1972). These color changes have been reported in numerous publications since the beginning of irradiation studies on meat. (Humber, et al., 1953, Hannon, 1954, and Ginger et al., 1955. They all reported color changes, but did not determine the cause of the changes. Hanson, 1953, found the color changes were more pronounced when foods were irradiated in the absence of oxygen. When the meat was cooked at 80 ^{O}C prior to irradiation the amount of red discoloration in the meat was reduced.

Tappel, 1957, described the formation of the bright red coloration of fresh meats when gamma-irradiated in an inert atmosphere. He postulated that the red color pigment was oxymyoglobin formed by metmyoglobin which reacted with hydroxyl radicals. He also found that when precooked meat was irradiated, the normal gray-brown pigments were converted to the red pigment.

Bernofsky, et al., 1959, claimed the red discoloration was due to the metmyoglobin reacting with the products of the water hydrolysis. They suggested that gamma irradiation caused the formation of hydroxy radicals which combined to form hydrogen peroxide and the red pigment compounds were formed by the combination of hydrogen peroxide and metmyoglobin.

Several techniques have also been developed using reflectance spectrophotometry for determining color changes in meat products. An accurate and precise method for determining the relative quantities of oxymyoglobin, metmyoglobin and the total pigment concentration at the surface of the meat has been developed. Reflectance spectrophotometry eliminates the need for extraction and allows the pigments to be evaluated in their natural environment. Franks and Salberg, 1971, described a method for determining the relative percent of metmyoglobin to the total pigment concentration.

Stewart, et al., 1965, also used reflectance spectrophotometry to determine the total color pigments and the percent of metmyoglobin. Strange, 1974 reported a simplified method for measuring meat color. These investigators used reflectance spectrophotometry and calculated linear correlation coefficients between a human sensory technological panel (using a hedonic scale) and reflectance values. They reported that the use of either colorimeters or reflectance spectrophotometers provided a quick and accurate replacement for panels using hedonic scales. Reproducibility is greater than for the technological panels.

Although these color changes can occur and are observed when the product is removed from the package, exposure to oxygen will cause the red colors to fade within five to ten minutes.

Tenderness

Tenderness is generally considered by the consumer to be one of the most important palatability characteristics of meat. Meat tenderness is measured subjectively by taste panels and objectively by mechanical methods. The most commonly used instruments are the Warner-Bratzler Shear Press ™ (Bratzler and Smith, 1963, Kramer, et al., 1951) the MIRINZ Tenderometer ™ (Macfarlane and Marer, 1966) and the Instron Universal Testing Machine ™ (Bouton, et al, 1971).

Factors which determine the tenderness of meat include: USDA grade, location of muscles, amount of connective tissue, post mortem aging, pH, muscles, method of cutting (with or against the grain), thickness of the cut and the method of cooking.

Bouton and Harris, 1972, found a very significant linear relationship on scores from the MIRINZ and Warner-Bratzler machines as measured on two muscles. The results correlated well with scores from sensory panels.

Field et al, 1971, found the correlation low between free amino acids and flavor in longissimus muscles. Histidine did not change as aging increased. As aging increased, tenderness and most of the free amino acids did also. However, correlations between specific amino acid content and tenderness were low.

Slatterlee and Lillard, 1967, believed amino acids to be important as flavor precursors in meat.

Sharrah, et al., 1965, found mechanical devices to differ in sensitivity and reproducibility and may measure different properties in meat; variation could exist within the same muscles; panelists differ in sensitivity and reproducibility and tend to give relative judgments within a set of variables; the use of only the correlation coefficient in relating objective and subjective measurements may not be sufficient; and, further measurement is necessary to establish the shear force that is meaningful in terms of sensory evaluation of texture and tenderness of meat.

The lack of agreement among investigators is probably due to the inability to

control the sources of variation. Mechanical devices differ in sensitivity and reproducibility. There is no standard sample available for reference or calibration. tenderness may vary within the muscle, depending on the cooking technique. Panelists vary considerably in sensitivity. Sensory scores are relative judgments (Sharrah, et al., 1965).

Materials and Methods

The samples were made from US Good grade fresh beef rounds consisting of semimembranosus, semitendinosus and biceps femoris muscles, seven to ten days post mortem.

Sample Preparation

Beef rounds were trimmed to three fat levels: A - 5%; B - 20 %; C - 20 % + 15 % added fat, for a total of 35%. The fat content was calculated by weight on a raw meat basis.

The beef rounds were cut in approximate 200 to 300 g chunks and mixed thoroughly for 15 minutes in a Model H-610 Hobart™ mixer, to produce a uniform mixture of lean and fat. Prior to mixing, the following were added: 0.75% sodium chloride (NaCl), 0.38% sodium tripolyphosphate (TPP) and 3% crushed ice. (All percentages are based on the initial weight of the meat.)

This mixture was ground twice through a 13 mm plate and then stuffed into 100 mm pricked cellulose casings.

Cooking

Cooking took place in a smoke house. The heating sequence was as follows: Two hours at 65 ^{o}C, followed by three hours at 77 ^{o}C, then seven hours at 94 ^{o}C, (or until an internal temperature of 70 ^{o}C was reached). The smoke house temperature was then lowered to 70 ^{o}C until the desired yield was obtained. The yield weight was 85 $\pm$ 2% of the starting weight. After cooking, the product was chilled to 2 to 3 ^{o}C within 24 hours. The ends of the rolls were trimmed off before removal of the casings.

Canning

The processed rolls were cut into 367 $\pm$ 1 g pieces, packaged in 404 x 202 cans with "meat enamel" lining and sealed with a minimum of 7 kPa of pressure. After sealing the cans were frozen to -25 ^{o}C and held until irradiation.

Irradiation Processing

The cobalt 60 (Co^{60}) source was used to achieve doses of 18.5, 37, 75 and 158, $\pm$ 12 %) kGy/kg, at a dose rate of 14.0 Gy/kg/sec. The samples were irradiated at temperatures of +5, -5, -15, -25, -45 and -80, $\pm$ 10 ^{o}C. The desired temperatures were obtained by placing the cans in an insulated container during irradiation and controlling the lower temperatures with liquid nitrogen. After irradiation, the samples were stored at 21 ^{o}C and tested at zero time and after one year. Control samples were kept frozen at -29 ^{o}C.

Testing Methods

Sensory

Samples were evaluated by trained, in-house technologists. Eight panelists were selected from a pool of approximately 30 persons.

A nine-point scale was used with one being "extremely poor" and nine being "excellent".

Preference scores were also obtained using a nine-point hedonic scale with nine being "like extremely" and one being "dislike extremely". The midpoint of five or "neither like nor dislike" was considered acceptable. (Peryam and Pilgrim, 1957).

Texture

The Kramer Shear Press ™ was used for the objective method of measuring texture (tenderness) in the beef samples. This instrument uses hydraulic pressure to force a series of parallel metal plates through the meat while it is held in a metal box. The shear press measures the maximum pressure required to force the plunger through the material (Schultz, 1957).

Samples were cut 13 mm thick x 25 mm x 50 mm and placed in the center of the box. Each sample was replicated 12 times and the results are reported in kPa.

Color

The reflectance in three color ranges, red (640 nm), green (546 nm) and blue (436 nm) was determined using a tristimulus colorimeter (Photonic, Inc. ™) with the instrument calibrated at 90% reflectance to a white calibration sheet. Twelve replications per variable were taken and the results are reported as percent reflectance.

Results

Sensory Tests

Technological Panel - Fat Level A (5%)

These results are presented in Table 1. The irradiation temperature was -25 ^{o}C. For all characteristics, irradiation gave lower scores when compared to the unirradiated control. Storage time had no effect on the sensory scores for color, texture, or preference.

TABLE 1 - EFFECT OF DOSE ON SENSORY SCORES (FAT LEVEL A)

	Sensory Characteristic						
Dose	Color		Texture		Preference		
kGy/kg	Mean	SD	Mean	SD	Mean	SD	8 member panel
A. No Storage							
Control	6.8	1.1	6.9	0.1	7.0	0.7	
37	6.2	1.1	6.2	1.0	6.0	1.3	
74	6.0	1.5	6.7	0.8	6.3	0.8	
B. One Year Storage							
Control	6.6	1.2	7.1	1.1	7.1	1.0	
37	5.6	1.4	5.5	1.5	5.9	0.9	
74	5.0	1.2	5.9	1.1	5.5	1.1	

Factor	Color		Texture		Preference	
	F	Signif.	*F*	Signif.	*F*	Signif.
Storage Time	2.76	nsd	1.22	nsd	0.74	nsd
Irradiation Dose	3.90	0.05	3.46	0.05	7.08	0.01
Time x Dose	0.02	nsd	0.47	nsd	O.33	nsd

Consumer Panel - Fat Level A (5%)

These results are presented in Table 2. Both the percent fat and the irradiation dose had a negative effect on the preference scores. Irradiation lowered the scores. There was no effect due to the irradiation temperature.

TABLE 2 - EFFECT OF DOSE AND FAT LEVEL ON PREFERENCE SCORES

Dose kGy/kg	Score / Fat Level A (5%) Mean	SD	B (20%) Mean	SD	C (35%) Mean	SD
Control	5.8	1.7	5.2	2.0	5.6	1.6
37	5.6	1.9	5.1	1.9	4.7	1.7
37*			5.4	2.0		
74	5.2	1.9	5.1	1.9	4.7	1.7
Panel Size	31		32		30	

All samples irradiated at -25°C except for 37* which was irradiated at +5°C

Factor	*F*	Signif.
Percent Fat	6.99	0.01
Irradiation Dose	3.22	0.05
Percent Fat x Dose	0.41	nsd
	t **	Signif.
Irradiation Temp.	0.75	nsd

F is for the analysis of all samples irradiated at - 25 °C and control

t is for the analysis of both samples irradiated with 37.0 kGy/kg

Technological Panel - Fat Level B (20%)

These results are presented in Table 3. Both the irradiation dose and storage time had a significant effect on the color and texture scores. Irradiation significantly lowered these scores. The samples had increased scores after one year of storage. Increasing irradiation dose had a negative effect on the preference scores. Storage time did not. All preference scores were acceptable.

TABLE 3 - EFFECT OF DOSE ON SENSORY SCORES (FAT LEVEL B)

Dose kJ/kg	Storage Time: No Storage Mean	No Storage SD	One Year Mean	One Year SD	8 member panel
A. Color					
Control	6.8	0.7	7.3	0.8	
37.0	5.5	1.3	6.4	1.2	
74.0	5.9	0.6	6.0	1.1	
B. Texture					
Control	6.1	1.1	7.1	0.9	
37.0	5.4	1.3	6.1	1.3	
74.0	5.3	1.4	6.0	1.1	
C. Preference					
Control	6.5	1.1	7.0	0.9	
37.0	5.5	1.4	6.1	1.2	
74.0	5.8	1.0	5.6	1.1	

All samples irradiated at -25 ^{o}C

Factor	Color *F*	Color Signif.	Texture *F*	Texture Signif.	Preference *F*	Preference Signif.
Irradiation Dose	24.3	0.01	4.8	0.05	3.2	0.05
Storage Time	7.4	0.01	8.4	0.01	1.8	nsd
Dose x Time	0.4	nsd	0.03	nsd	0.04	nsd

Consumer Panel - Fat Level B (20%)

These results are given in Table 4. There was no significant effect due to the dose, although the scores were lowered when compared to the unirradiated control.
All the samples with the exception of the 148.0 kGy/kg sample had acceptable preference ratings.

TABLE 4 - EFFECT OF DOSE ON SENSORY SCORES (FAT LEVEL B)

	Sensory Characteristic					
Dose	Color		Texture		Preference	
kJ/kg	Mean	SD	Mean	SD	Mean	SD
Control	6.8	0.7	6.1	1.1	6.5	1.1
18.5	5.5	1.5	5.4	1.6	5.5	1.6
37	5.5	1.3	5.4	1.3	5.5	1.4
74	5.9	0.6	5.3	1.4	5.8	1.0
148	5.1	1.2	5.0	1.5	4.6	2.1
F	2.4	nsd	1.0	nsd	3.6	nsd

32 member panel

Irradiation temperature was -25 °C

Technological Panel - Fat Level C (35%)

The results are given in Table 5.

The only significant effect shown was that of irradiation dose on texture. After one year of storage the sample that received the 74 kGy dose had a better texture rating than the sample that received the 37 kGy dose. This is not explained.

The irradiated samples did not receive significantly lower color score. Although they did receive lower preferences scores, it was not significant.

TABLE 5 - EFFECT OF DOSE ON SENSORY SCORES (FAT LEVEL C)

8 member panel

Dose kGy/kg	Storage Time: No Storage Mean	SD	One Year Mean	SD
A. Color				
Control	6.1	1.2	6.1	0.9
37	5.8	1.1	6.0	0.5
74	5.4	1.5	6.0	1.1
B. Texture				
Control	6.6	0.9	6.4	0.7
37	5.3	1.3	5.5	1.1
74	5.1	1.3	6.0	1.1
C. Preference				
Control	6.5	1.1	5.8	1.0
37	5.9	1.4	5.1	0.9
74	5.0	1.2	5.3	1.4

All samples were irradiated at -25 ^{o}C.

Factor	Color *F*	Color Signif.	Texture *F*	Texture Signif.	Preference *F*	Preference Signif
Irradiation Dose	0.4	nsd	5.3	0.01	2.8	nsd
Storage Time	0.4	nsd	1.8	nsd	1.4	nsd
Dose x Time	0.3	nsd	0.5	nsd	0.4	nsd

Effect of Irradiation Temperature on Sensory Scores

These results are given in Table 6.

The irradiation temperature had no effect on any of the sensory scores.

TABLE 6 - EFFECT OF IRRADIATION TEMPERATURE ON SENSORY SCORES (FAT LEVEL A

Irradiation Temp.	Sensory Characteristic						
	Color		Texture		Preference		
°C	Mean	SD	Mean	SD	Mean	SD	48 member panel
+5	6.1	0.8	5.5	1.0	5.1	0.8	
-5	6.0	0.9	6.0	0.9	5.4	0.9	
-15	5.8	0.8	6.1	1.1	5.6	0.9	
-25	6.1	0.8	6.1	1.1	5.6	0.9	
-45	6.0	1.1	6.1	1.2	5.8	0.7	
-80	6.4	0.5	6.5	1.0	6.0	1.0	

Factor	Color		Texture		Preference	
	F	Signif.	*F*	Signif.	*F*	Signif.
Irradiation Temperature	0.5	nsd	0.8	nsd	1.1	nsd

Effect of Fat Level on Sensory Scores

These results are given in Table 7. For the color scores, the leaner the meat, the higher the score, although no significant differences were shown. The texture and preference scores did not show any trends that could be attributed to the fat level.

TABLE 7 - EFFECT OF FAT LEVEL ON SENSORY SCORES

Fat Level	Sensory Characteristic						
	Color		Texture		Preference		
	Mean	SD	Mean	SD	Mean	SD	8 member panel
A (5%)	6.6	0.7	6.1	1.5	5.1	1.5	
B (20%)	6.3	0.8	5.9	1.2	4.6	1.7	
C (35%)	5.3	1.1	6.0	1.1	5.1	1.7	
Control (20%)	6.5	0.5	6.5	0.9	6.1	1.2	
F	1.2	nsd	0.4	nsd	1.2	nsd	

Irradiation Conditions - 37 kGy dose at -25 °C

Texture

Kramer Shear Press

These values are shown in Table 8. All principal factors, storage time, percent fat and irradiation dose had a significant effect on the shear press values. This was also true for all the interactions. The values decreased with storage time. The values decreased with increased fat content. The values also decreased with increased dose.

TABLE 8 - EFFECT OF DOSE RATE, STORAGE TIME AND FAT LEVEL ON TEXTURE

Dose	Fat Level											
	A (5%)				B (20%)				C (35%)			
	Storage Time, Years				Storage Time, Years				Storage Time, Years			
	0		1		0		1		0		1	
	Shear Press Value, kPa											
kGy/kg	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control	58.1	5.4	47.2	5.3	45.3	5.1	46.5	5.7	43.2	3.8	35.1	3.8
18.5	45.7	2.9	35.7	2.3	38.0	5.9	28.4	4.0	31.6	2.0	25.9	3.0
37	40.8	3.4	28.2	2.0	37.5	7.3	20.3	2.5	30.8	3,4	20.1	3.1
74	37.3	4.2	26.8	1.8	26.3	2.7	19.8	2.0	27.3	3.3	17.1	2.0
148	36.6	2.6	30.1	3.2	23.5	1.9	17.3	2.1	20.9	2.0	19.0	3.0

All samples irradiated at -25 ^{o}C 12 replicates per test

Factor	F	Signif.
Storage Time	573	<0.001
Percent Fat	388	<0.001
Irradiation Dose	487	<0.001
Time x Fat	2.5	0.05
Dose x Fat	4.0	0.01
Time x Dose	8.3	0.01
Time x Fat x Dose	2.1	0.01

Color

These results are shown in Table 9. The irradiation temperature had a significant effect on all three values when compared to the unirradiated control.. Irradiation increased all three values. Although there were differences, there was no trend for increased color values with irradiation temperature.

TABLE 9 - EFFECT OF IRRADIATION TEMPERATURE ON REFLECTANCE COLOR (FAT LEVEL B)

12 replicates per values

Irradiation Temperature °C	Color					
	Blue		Green		Red	
	Mean	SD	Mean	SD	Mean	SD
Control	16.3	2.2	20.3	1.7	54.9	2.7
+5	20.8	1.3	21.4	1.0	71.3	1.6
-5	18.4	1.6	19.8	1.2	68.2	1.7
-15	20.0	1.9	22.8	1.7	68.8	2.5
-25	18.2	1.5	21.1	1.8	64.9	1.9
-80	18.6	1.3	21.3	1.1	61.4	2.3

Factor	Color					
	Green		Red		Yellow	
	F	Signif.	*F*	Signif.	*F*	Signif.
Irradiation Temperatire (not including control)	10.8	0.01	12.8	0.01	91.7	0.01

Conclusions

Sensory

Irradiation lowered sensory scores. Storage time had little effect. Temperature of irradiation had little effect. The total dose had little effect. Lower fat levels tended to give higher color scores. The fat level had no effect on texture or preference.

Texture

Storage time, percent fat and irradiation dose all had a significant effect in decreasing the shear press values. The interaction of each of these factors had a similar effect.

Color

Higher Irradiation temperature increased the score of the values of all three colors as compared to the control but there was no correlation between the irradiation temperature and the score.

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